FRANKLIN

National Facility
Oceanographic Research Vessel

Tasman-Coral Sea Mass and Heat Transport / Satellite Altimeter Verification.

CRUISE SUMMARY

RV FRANKLIN

FR 02/99

Leg 1. Sailed Brisbane 1100 hrs, Friday 12 March, 1999.
Arrived Brisbane 0700 hrs, Thursday 25 March, 1999.

Leg 2. Sailed Brisbane 2000 hrs, Thursday 25 March, 1999.
Arrived Noumea 0800 hrs, Friday 9 April, 1999.

Principal Investigators

Mr. Ken Ridgway (Chief Scientist)
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GPO Box 1538, HOBART TASMANIA 7001

Mr. Rick Bailey
CSIRO Marine Research

Assoc. Prof. Richard Coleman
CSIRO Marine Research/University of Tasmania

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Mr. Rick Bailey, CSIRO Marine Research

Assoc. Prof. Richard Coleman, CSIRO Marine Research/University of Tasmania

Scientific Objectives

- to contribute to the development of an operational marine monitoring and nowcast system (Oceans-EEZ) for Australian waters, which also forms part of the Global Ocean Observing System (GOOS).
- to gain an understanding of the basin-scale ocean variability within the Tasman and Coral Seas as part of the international Climate Variability program (CLIVAR).
- to improve our understanding and modelling capacity of the EEZ
- to assess our ability to monitor ocean fronts and quantify heat transport using in-situ and satellite data
- to provide a benchmark calibration dataset using a variety of ocean sensors

Cruise Objectives

- Obtain ground truth observations along a T/P altimeter track which traverses the EAC at the coast. Using concurrent ADCP measurements, derive absolute surface currents and obtain an estimate of the "oceanographic" geoid along the track

- Obtain in situ observations of surface steric height around a complete altimeter 'diamond' and across the diamond to provide ground truth for altimeter observations and to assess and improve existing altimeter horizontal interpolation schemes

- Assess the validity of inferred subsurface temperatures from surface satellite altimeter/SST observations and improve existing vertical projection schemes

- Obtain closed volume observation around the diamond and compare direct transport closures with estimates derived from satellite observations

- Compare sea surface height profiles obtained from altimetry, hydrographic and towed GPS buoy data.

- Investigate and inter-compare procedures for computing absolute surface currents using GPS data collected from the ship ADU and from long range kinematic GPS solutions.

- Calibrate and evaluate XBT and XCTD instrumentation against the CTD.

- Obtain sea surface temperature (SST) to validate the MODIS, ATSR-2 and AVHRR satellite instruments

- Collect data to assist with the development of ocean colour algorithms using SeaWiFS, MODIS, and other ocean colour data.

- Occupy the Brisbane-Fiji section as part of the long-term monitoring of the mass and heat transport in the Tasman Sea.

- 'Value add' to the 8 years of high density XBT data (1991-99) collected along this route from merchant vessels by achieving the following:

    - assess the errors involved in obtaining dynamic height from XBT temperature profiles along the section

    - quantify the contributions to the baroclinic flow below 800 m along the section

    - assess the validity of steric height and temperature extrapolation schemes

    - determine a revised sampling strategy to enable the section to be maintained in the long term with a combination of satellite and in-situ data collection.

Cruise Track

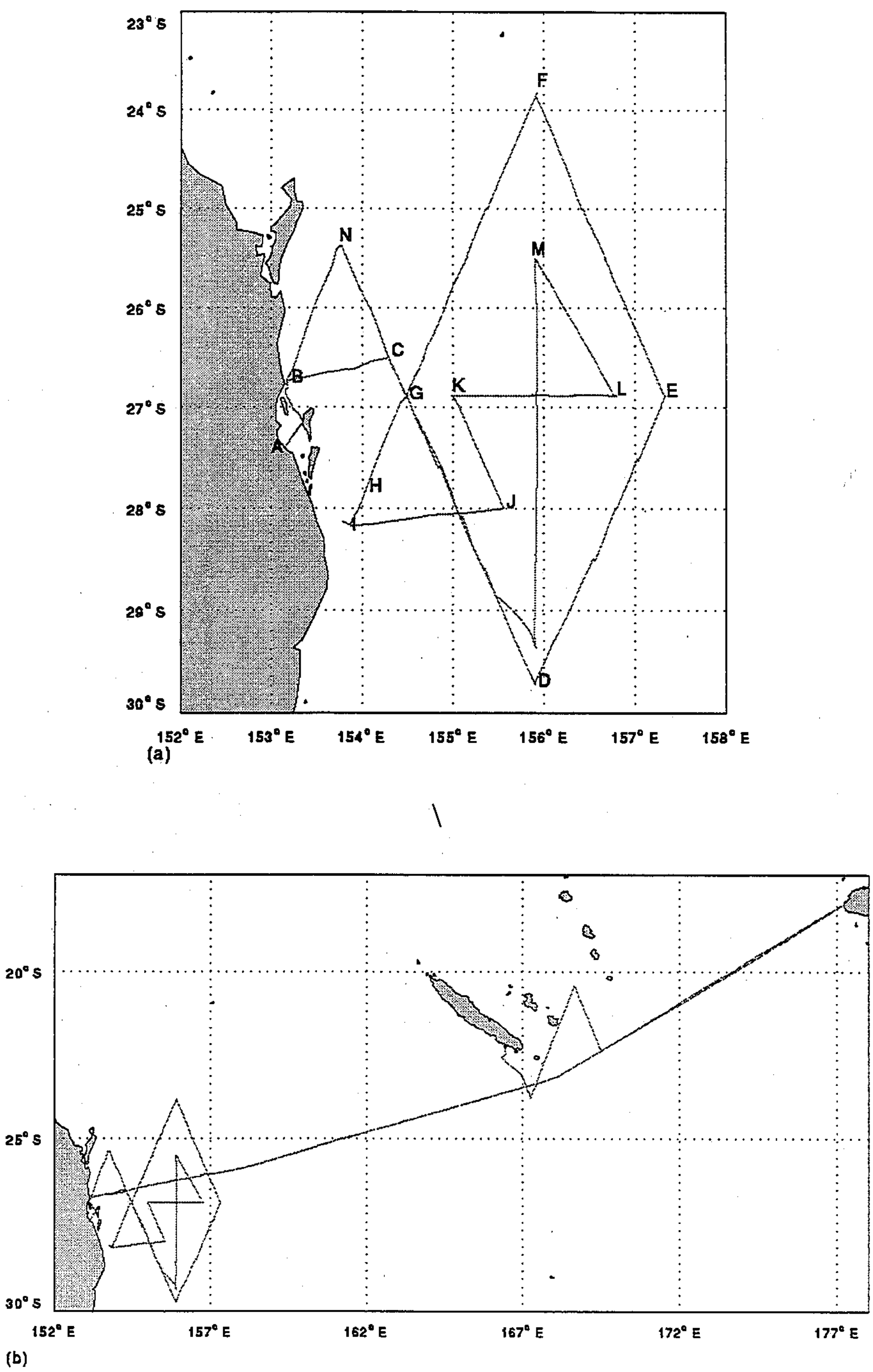

Figure 1 The cruise track of (a) leg 1, and (b) the entire cruise.

Results

Much of the data processing from the cruise has still to be completed and the satellite altimetry data is not yet available for comparison with the in-situ data. Therefore, the following discussion and results presented are based on an initial consideration of data that has only undergone a preliminary calibration.

Following the cruise plan, SeaSoar transects were obtained along segments of 2 satellite tracks with concurrent ADCP observations and 3DGPS data. On one section (DN) there are data gaps when the SeaSoar was inoperative but we are able to interpolate across these gaps using XBT data which was also collected (Figure 2). Problems were also experienced with the 3DGPS (data dropouts and some background noise). Despite these glitches we believe that the data will enable an accurate estimate of the mean surface current to be determined and hence an ongoing time series of the flow of the EAC to be obtained from the satellite altimetry data.

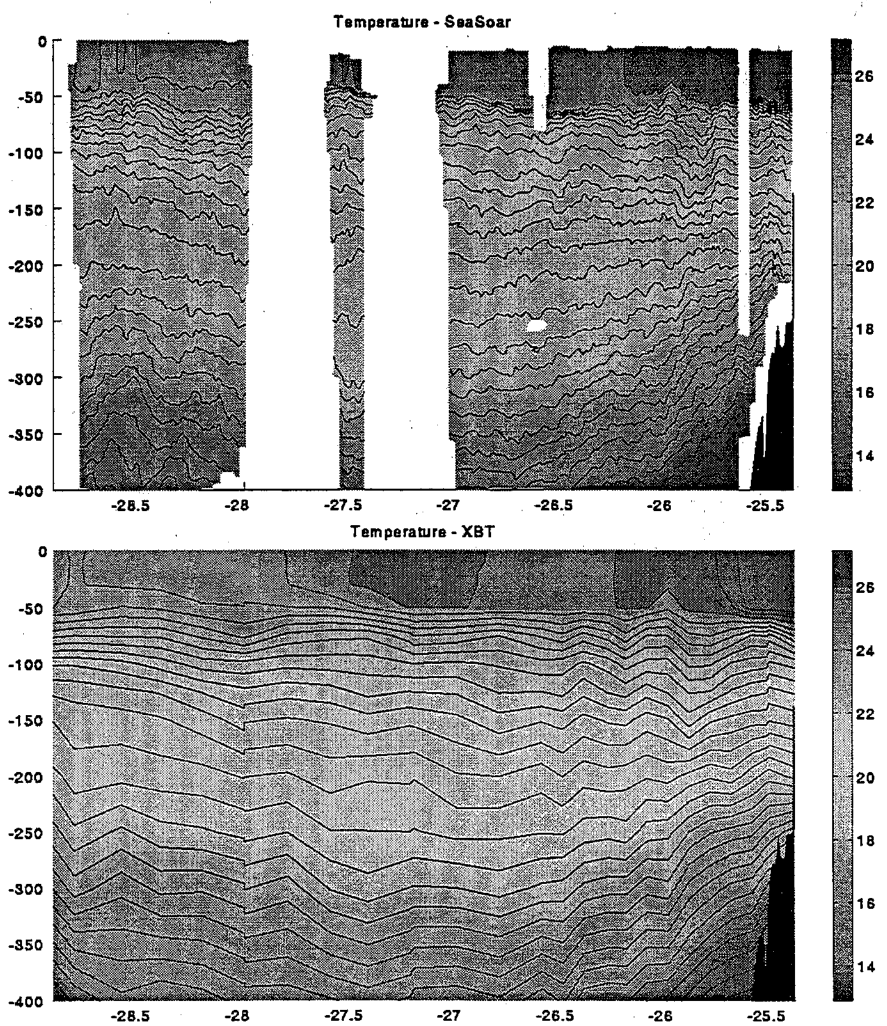

Figure 2 Temperature along DN from (a) SeaSoar and (b) XBTs.

Full-depth CTD stations were occupied both around and across the altimeter diamond at 25-50 km spacing. In addition XBTs were dropped between the CTDs and also on a track to 'fill out' the interior of the diamond. The latter set of XBTs obtained data down to 1800-m. Steric height will be obtained from this collection of casts and used to assess the interpolation schemes which produced the gridded height anomaly fields from the standard altimeter data (obtained only on the tracks). The availability of the CTDs enables an accurate T-S relationship to be determined and hence a more accurate steric height calculation from the XBTs.

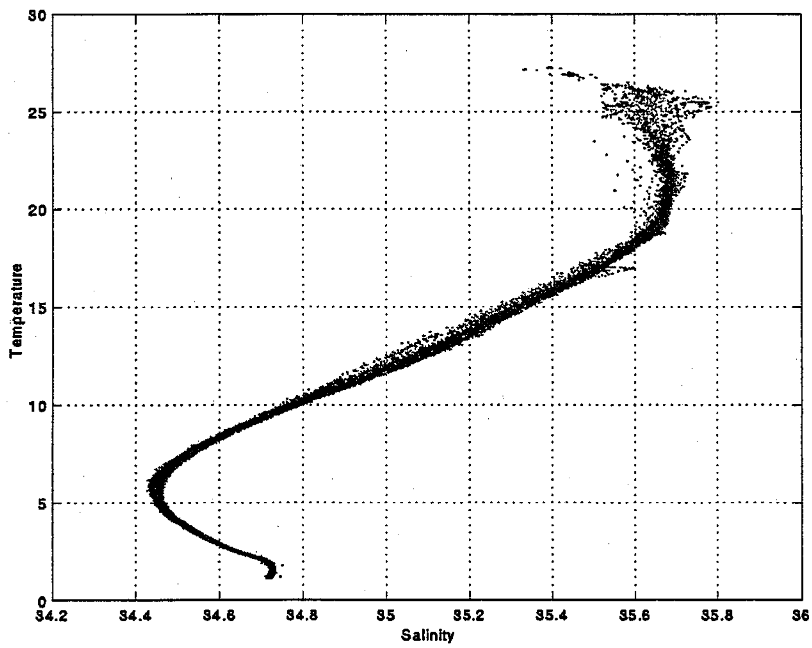

Figure 3 Temperature – Salinity relationship from the CTD casts collected in leg 1

The in-situ data along the altimeter tracks enables a test of schemes which infer subsurface structure from remotely sensed surface observations. It was planned to obtain both SST and surface height fields in 'near real-time' and compare the inferred sections from these data with the actual observations. Unfortunately, this was not possible. Production of the fast delivery altimeter product was stopped 2 weeks before the cruise due to a changeover of the satellite sensor. Although it was disappointing that we could not successfully complete this real-time demonstration of the capability, the satellite data will be available in a delayed mode and the objective will be met at some later time.

The full-depth CTDs will allow us to obtain mass and heat transport closure around the diamond. Again we have the dataset that allows us to assess the capability of the satellite data alone to estimate the transport.

Observations of sea surface height along the tracks from the CTDs and XBTs will be compared with the altimetric height anomalies to determine the relative contributions of the baroclinic and barotropic components. We had planned to collect data from a towed GPS buoy for the duration of the cruise, but this was not constructed (an overseas colleague had to pull out of the cruise) in time for the cruise.

Comparisons are to be made of the absolute surface currents (objective 1) obtained using the 3DGPS, gyro and from long range kinematic GPS solutions. This is particularly relevant with the problems experienced by the ASHTEC system. In addition, since both SeaSoar and CTD data were obtained along one altimeter track, we will assess the feasibility of determining the absolute currents from CTDs and geostrophic methods. The surface currents as observed by the ADCP are shown in Figure 4. The EAC is clearly evident with currents between 1-2 ms^{-1} with a much more complex circulation pattern further offshore.

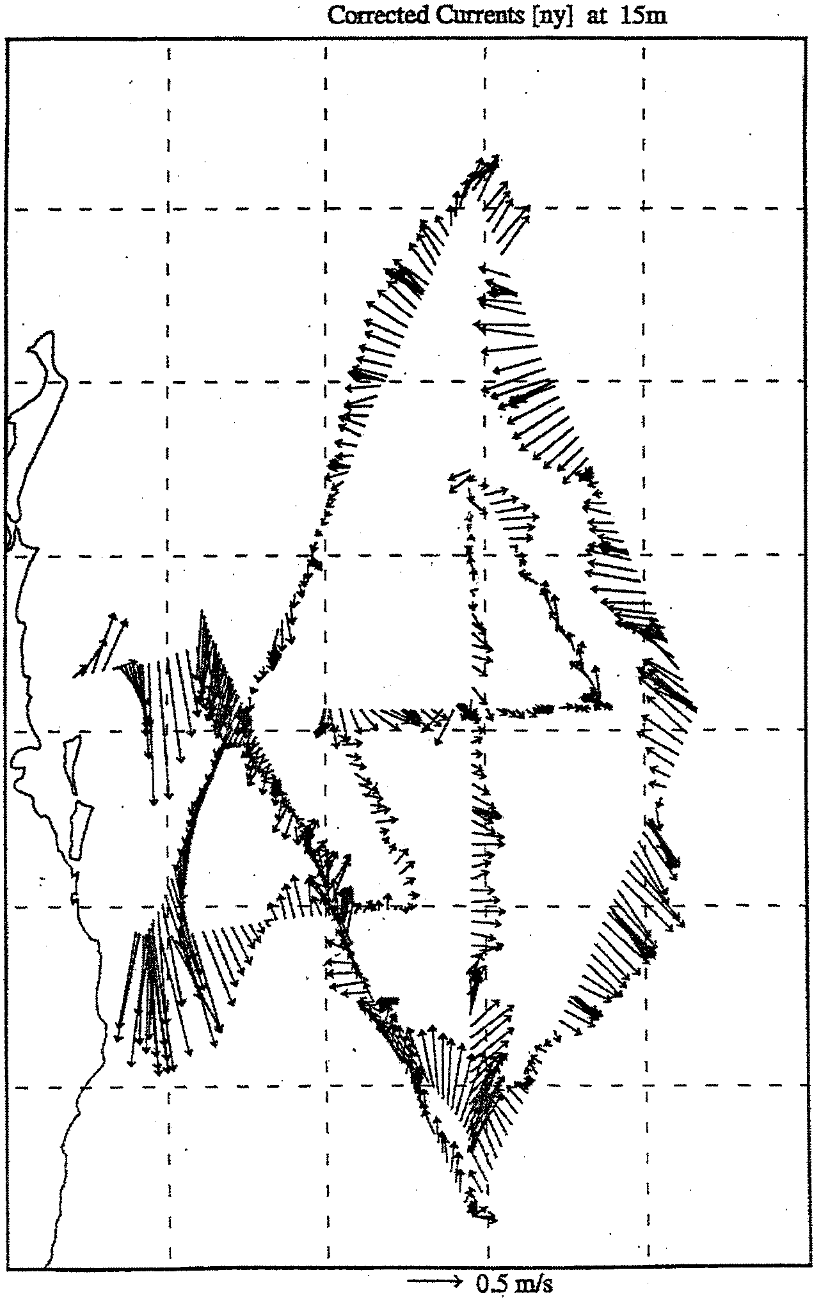

Figure 4 Surface currents along the track of leg 1 from the ADCP

A whole range of comparisons were performed between different types of XBT casts, logging systems and CTDs. We obtained data concerning XCTDs (TSK and Sippican), T5 XBTs, Franklin and BOM logging systems. These results will be used to both assess the capabilities of the probes and the utility of the data collection systems.

Three infrared radiometers were operated almost continuously during both legs of the voyage. Each radiometer was mounted to view a similar patch of water just outside the wake on the starboard side of the vessel. The radiometers used were -

- A high quality self-calibrating radiometer with a noise figure of 0.03K and an absolute accuracy of 0.1K. The spectral pass-band is one micrometer centred on 11 micrometres (similar to AVHRR Channel 4). This radiometer was occasionally pointed to the sky.
- A self calibrating TASCO radiometer which also viewed the sky radiance every ten minutes. These first two radiometers were mounted on the bridge deck.
- A single TASCO radiometer set in a fixed position above the bridge.

The measurements from these radiometers will be compared with each other and with those from the thermosalinograph and CTD. This will enable an assessment of the performance of the two TASCO radiometers, and allow the "skin effect" to be determined. The output from the three infrared radiometers are plotted with the thermosalinograph temperature in Figure 5. The DAR011 radiometer output has not been smoothed and the output shows the noise temperature of the radiometer plus the fluctuations due to ship movement and waves on the sea surface. The TASCO radiometer outputs are averaged over 1 minute periods. The fluctuations in the radiometer outputs compared to the thermosalinograph are due to the reflected sky radiance. The peaks are due to the reflection of passing clouds. The radiometer outputs will all need to be corrected for this reflected sky component. When this is done the difference between the radiometer measurements and the thermosalinograph is the "skin-effect".

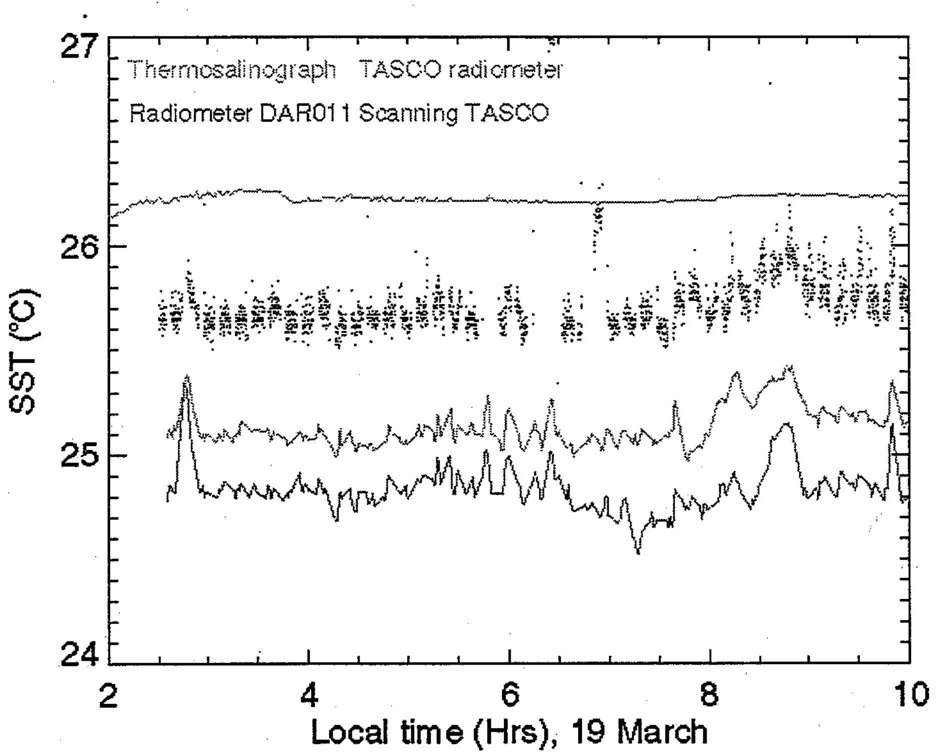

Figure 5 The three infrared radiometers are plotted with the thermosalinograph temperature

Ten radiosonde balloons were launched during the cruise. These were released at times when ERS-2 was passing overhead. This will assist in the validation of SST measurements from ATSR-2 data. The sonde measurements will allow the use of an atmospheric model to confirm the correction required for atmospheric water vapour absorption.

Eleven ATSR-2 infrared brightness temperature images have been obtained. An early analysis suggests that several of these are relatively free of clouds, and the data should assist in future analysis of the voyage data.

Unfortunately due to a shortage of available personnel the ocean colour project could not be carried out.

The second leg of the cruise was a full-depth CTD section from Brisbane to Fiji. This followed the track taken by container ships which have participated in a high-density XBT project for over 8 years. The temperature and salinity transects are shown in Figure 6. The surface waters (< 100 m) freshened steadily as we moved to the east reaching a minimum of 34.2 at 177.2°E. This represents the path of fresh water outflow from the PNG north coast. At a depth of 100-200-m the presence of Sub-Tropical Lower water (SLW) was indicated by a salinity maximum. This increased to the east, with maxima observed at several locations east of 172°E. At 176.8 °E salinities above 36.0 were observed. This also showed a very large salinity gradient over the upper 180 m.

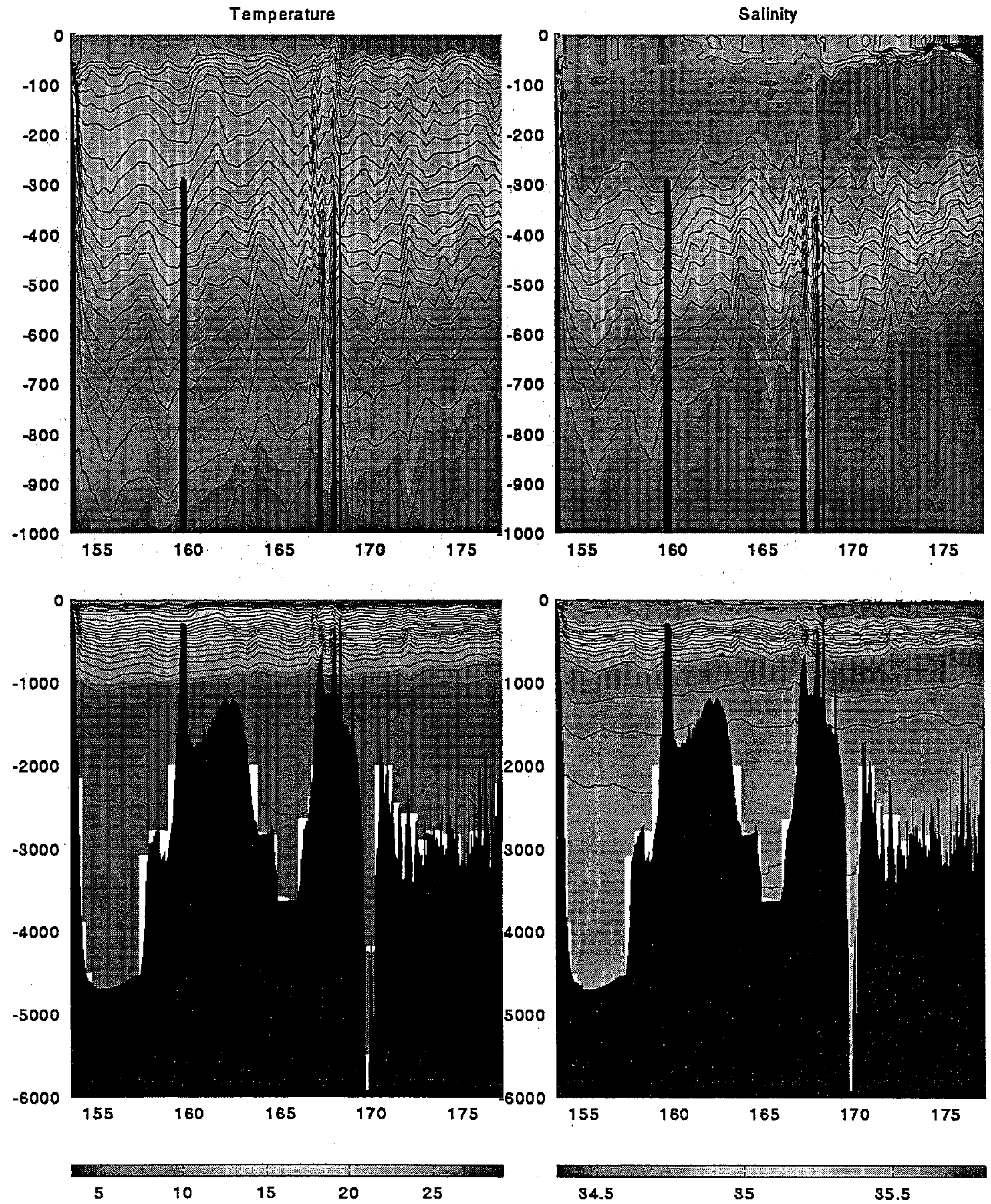

Figure 6 Temperature and salinity sections along the transect from Brisbane to Fiji

The typically strong East Australian Current (EAC) was observed just on the continental slope with surface currents greater than 1.0 ms^{-1} and a volume transport magnitude of 30-Sv. The surface currents along the whole section as shown by the ADCP are given in Figure 7. Note the evidence of substantial eddying activity, with alternating currents of order 0.5 ms^{-1} throughout the section. The strong southeastward flow adjacent to New Caledonia has currents approaching 1.0 ms^{-1}.

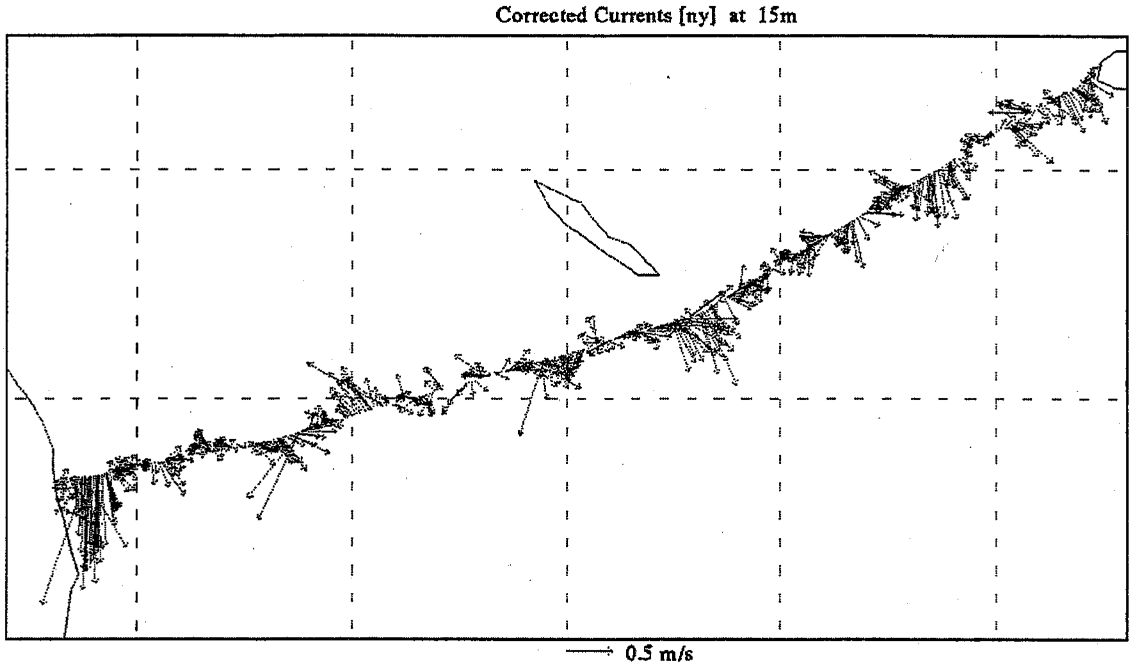

Figure 7 Corrected currents at 15-m from the ADCP along the Brisbane – Fiji section

The net transport across the whole section was actually about 20-Sv to the north. This was made up of contributions from the South Equatorial Current (SEC) between New Caledonia and Fiji (25-Sv) and a massive northward component between 160°-164°E of 40-Sv. The EAC is a relatively narrow and intense jet while the other flows are much broader, occurring mostly below 400-m (hence no particular signature at the surface). The cumulative transport (starting at Fiji) is shown in Figure 8.

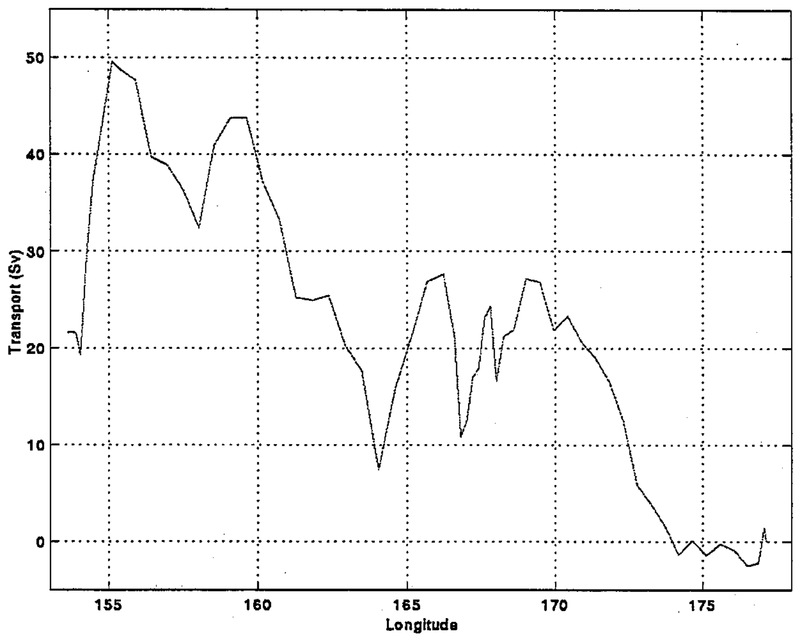

Figure 8 The cumulative volume transport across the section (referenced to Fiji).

In the vicinity of New Caledonia we observed highly energetic internal waves in both the T and S sections (Figure 9). Vertical amplitudes of more than 150-m are clearly seen in the 300-700-m depth range. These features have been also observed in the XBT temperature profiles and so the CTDs were closely spaced to resolve the waves in some detail.

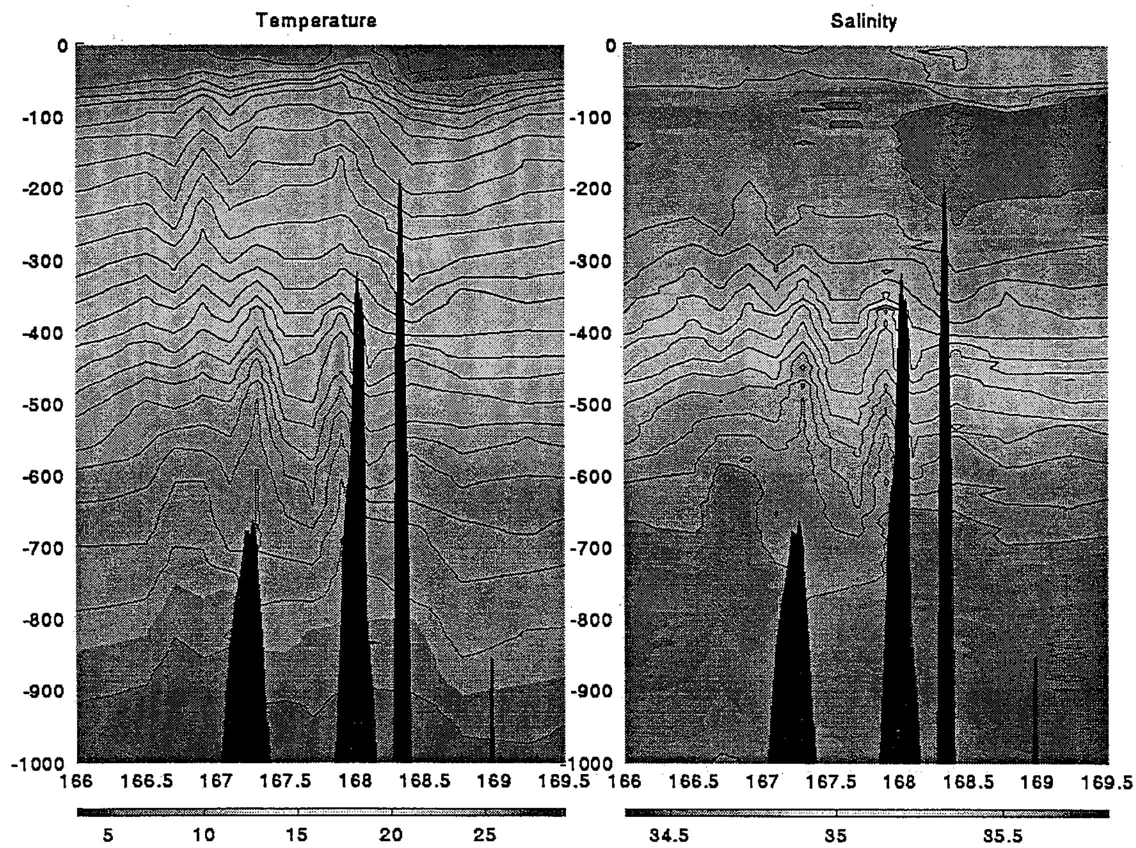

Figure 9 Internal wave structure in both temperature and salinity sections

The collection of both salinity data and full-depth sections enables several uncertain aspects of the results gained from the previous time series of XBT sections to be assessed. In particular, we are able to determine the accuracy of the T-S method for calculating steric height (and transport) directly from XBT temperature profiles and to quantify the extent of sub-800-m baroclinic flow and the ability of vertical extrapolation schemes. For example, in Figure 10, we show the cumulative transport along the section from the observations compared with that determined using the T-S method and with the result using a vertical temperature extrapolation method. Both methods appear to generally over-estimate the transport along the section but still obtain the net transport to within 3-Sv.

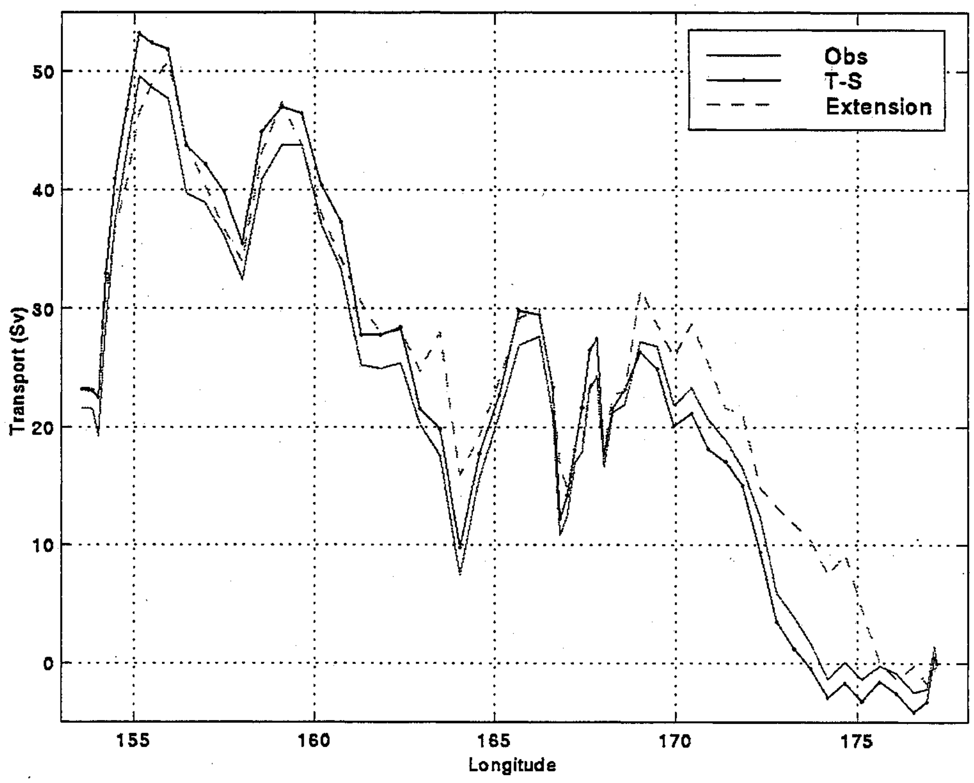

Figure 10 Comparison of cumulative transport obtained from observations alone with that from the T-S and extension methods.

With near perfect weather conditions for much of the second leg we completed the section some 40 hours ahead of schedule. This allowed an extra component to be included in the cruise. This consisted of XBT surveys along a further 3 portions of satellite tracks to the east of New Caledonia. The timing was such that the surveys were carried out within 2-3 days of the satellite passing overhead. The availability of recent T-S data allows extremely accurate salinity estimates to be obtained from the temperature profiles and the casts are spaced closely to resolve the horizontal structure along the transects.

These results will contribute to a revised sampling strategy for the section which uses a combination of satellite and in-situ data monitoring.

Summary of Data Collected

CTD profiles
A total of 92 full-depth CTD profiles were obtained using 12 bottle rosettes. Samples of oxygen, salinity, NO_3+NO_2, SiO_2 and PO_4 were obtained.

SeaSoar
The SeaSoar was deployed on two extended sections down to 400-m depths.

XBTs
A total of 290 XBTs were dropped along both legs of the cruise. These consisted of 12 TSK XCTDs, 72 T5s, 100 deep blue with the remainder being T7 XBTs.

Underway
Observations were collected from the ADCP, GPS (ASHTEC), thermosalinograph, and a suite of meteorological sensors for the duration of the cruise.

SST
Three infrared radiometers were operated almost continuously during both legs of the voyage and ten radiosonde balloons were launched when crossing ERS satellite tracks.

Cruise Narrative

We departed Brisbane at 1100 in sunshine and clear skies and proceeded to the first waypoint at the beginning of section BC. We were under pilotage until 1700 and reached the waypoint at 2000. The speed of the ship was kept low to allow extra time for the SeaSoar to be prepared for deployment but despite the best efforts of the SeaSoar 'team' it was not ready at this time. We therefore proceeded along the section (BC) at low speed (4 knots) and began launching XBTs while the final stages of the SeaSoar preparation were completed. While the weather was still good a moderate swell had developed which made the final adjustments of the equipment rather trying. At 2100 all was in readiness and the launch procedure was initiated. Unfortunately, at this stage the cable became dislodged from the pulley, forcing the launch to be terminated and the SeaSoar deployment abandoned. The fact that this was the first such occurrence of such a problem since the SeaSoar began operation several years ago did little to ease our disappointment. We continued to deploy XBTs every 12 nm along the rest of the section, and the end point was reached at 0040 (March 13). The usual strong EAC flow was evident in the lateral component of velocity acting on the ship

Reaching point C also meant that we were now to begin a traverse along the TOPEX/POSEIDON satellite track (CD). The satellite actually followed along the track some 13 hours previously but the difference in time was small enough to not be a significant problem. We began a sequence of 9 full-depth CTDs along the section. Most of them were greater than 4500 depth and were positioned about 30-nm apart. We launched XBTs (T7) between the CTDs to provide an increased spatial resolution of the surface height fields. In addition deep blue XBT probes were deployed at the actual CTD stations to test both the accuracy of the probes and also the logging system. The wind was fairly steady from the SE at about 10-15 knots with low swell. The CTD display began giving problems with erroneous traces appearing on the screen. During CTD 5 there was a failure in the hydraulics of the winch and this caused a loss of power for more than an hour. The display problems persisted and so the original unit (10) was replaced with unit 8 but this did not improve the situation and so the units were switched back to the initial set-up. We had made up the time that was lost on the first day and we were now just about on schedule. The end of the section was reached at 0445 on March 15. There were some problems with the ASHTEC 3DGPS system and it only became operational on March 16. It was run with the ADCP for a day but frequent dropouts caused the loss of ADCP data. It was decided to log the raw 3DGPS data but run the ADCP with gyro data. This configuration was maintained for the remainder of the cruise.

The next transect (DE) was again along a satellite track but by this time we were just over 48 hours behind the satellite traverse. The experimental design of this transect was similar to the previous one, CTDs every 30 nm, interspersed with XBTs. In addition test casts were performed at each CTD of TSK XCTDs. These reach depths of 1000 m and with a US$1000 price some degree of care was applied to each drop. Fortunately all but one appeared to be successful. The weather remained fine with southeasterly winds in the range 5-15 Knots. At 2200 a met balloon was released successfully. A further 5 CTDs were completed on the section and the section ended at 1000 on the March 16. The third transect of the diamond was then commenced (EF) some 24 hours after the satellite passed overhead. We steadily gained time on our schedule while the good weather continued although the wind had increased somewhat to 15-23 Knot with moderate swells. As a test of the SeaSoar operation a deployment was performed at 1600 on March 16 and returned on board at 1730. All systems were performing according to specifications so this gave confidence for the forthcoming extended deployments. The section was completed by CTD 20 at 2000 on March 17.

The section FG was next, the final side of the diamond and we were again only 24 hours behind the satellite. A further 6 CTDs were completed, again interspersed by XBTs. At 2200 on March 18 another met balloon was successfully released. The wind by now had shifted more to the east at about 18-23 kn which made conditions initially slightly uncomfortable. Point G was reached and CTD 25 completed by 0200 on March 19. At this time SeaSoar was deployed for an extended transect crossing over the continental slope and shelf. The wind was moderate in the range 12-15 knots still from the east and the sea was moderate making ideal conditions for towing SeaSoar. The section was completed without any problems and the SeaSoar was successfully recovered. Opportunity was now taken to conduct some tests on the ADCP and gyro. In fact, the gyro test was quickly aborted due to problems in the timely collection of the relevant data. However, an ADCP test was carried out successfully which consisted of steaming along alternate perpendicular sections

The cruise track now departed from the satellite tracks and headed for the centre of the diamond and point J. XBTs were dropped at intervals of 15 nm. The section JK was now commenced at 0700 March 20 and for the first time the deep XBTS (T5) were dropped. These reach down to 1800 m if the vessel speed is kept below 6 knots. The wind remained easterly at about 18-20 knots with occasional showers and moderate swell. At 1330 (March 20) the section KL was commenced. This consisted of 5 CTDs with the usual XBTs in between. We used T7 XBTs in this case rather than the deeper T5s. The wind shifted to a northeasterly at 15-20 knots and several showers were experienced in following along the transect. Point L was reached at 1900 and CTD (#31) was completed. An XBT only transect (LM) followed again deploying the deep T5 XBTs at 15 nm intervals.

A long section MD was then to complete the segment within the diamond. This was again to deploy only XBTs, but since a considerable amount of time had been made up on the original schedule extra CTD stations were added to the cruise plan. The wind was now from the north at 15-18 knots. Only 2 extra CTDs were actually completed as it was decided to retain some time in reserve for the final SeaSoar transect. The CTD display problem was finally solved – it was in software after all. The forecast was for strong winds and suddenly at 2200 (March 22) the front came through with the southerlies averaging 50 knots gusting to 70-80 knots. This served to flatten the existing swell that had built up from the north and so conditions remained quite comfortable. The wind very soon moderated to the 30-35 knot range and the seas became quite rough. Since we were now heading directly into this weather it was decided to abort the section and steam immediately to the final satellite track DN. Due to the direction of the wind this could only we managed by adopting a slightly oblique angle and the section was actually reached at 0500 on March 23. The SeaSoar was then launched and towing began in rough seas (6/7) although fortunately the wind was southeasterly (directly behind us). These lively conditions remained for the entire transect but the main difficulties were with the equipment. A series of cabling faults necessitated the recovery and redeployment of SeaSoar on 2 occasions. Overall the data collected were satisfactory with some gaps. XBTs were dropped along the section at high resolution (6-12-nm) which should enable the gaps to be filled adequately. A 'school' of dolphins accompanied us for over an hour, entertaining everyone with their antics. The end of the section was reached at 1400 March 24 and SeaSoar was successfully recovered for the final time. The leg was completed by steaming to the pilot pick-up point and returning to Brisbane for change of staff, unloading of equipment and loading of gear for the next cruise.

We left Brisbane on the second leg at 2000 on March 25. The first way-point was soon reached at 0300 (March 26) and we began the first CTD of the long section to Fiji. This sequence of 8 stations were over the slope, and being closely spaced and in shallow water, were completed rather quickly. The wind was from the southeast (15-20-Kn) and the seas had livened up causing considerable discomfort amongst some of the new staff. To resolve the flow of the EAC the CTD stations were still quite closely spaced (12-nm) with XBTs in between. The first met balloon for the section was released during CTD 17 at 2200 March 28. The seas had moderated considerably by this time and the wind was down to 5-10 knots. These conditions were fairly typical for much of the time on this leg.

Comparisons of the T5 XBTs with CTDs were planned and several were attempted. However, with up to 1800 m of wire out, a stationary vessel and light winds it was difficult if not impossible to avoid failures due to the wire contacting the ship's side. Instead, in between the CTDs we performed T5 drops immediately after the shallower (and well tested) T7 probes. Launching the probes with the ship's motion assisting, the failures were almost eliminated. Continuing problems were experienced with the ship's communications. While in Mobilesat range, it worked perfectly including email. However, once moving onto Inmarsat B the data link proved to be very unreliable and connection was only achieved rarely and then only after many attempts.

On reaching the vicinity of New Caledonia the CTD sampling was increased to resolve the internal wave activity that had been observed previously in the XBT transects. We managed to detect highly energetic waves with amplitudes of more than 150 m in both the temperature and salinity results. With the continuing good weather we steadily moved ahead of schedule. The cruise had settled down to a very regular pattern of steaming to station, completing a CTD, steaming to the next station, with XBTs in between. The smooth running of the data collection was not even disrupted unduly when bottle numbers became scrambled. We crossed the New Caledonian Trench and completed a CTD to 5500 m, some 500 m from the bottom at 2030 on April 1.

The end of the section was reached at 0440 on April 5 (we at least sighted Fiji). By now we were more than 30 hours ahead of schedule and this extra time allowed some modification of the cruise plan. We proceeded back along the outgoing track until we reached a descending satellite track between New Caledonia and Vanuatu (0100 April 7). The timing was such that we were within 2-3 days of each satellite overpass for the following series of tracks. We then took a northwestward course along the track and began an intensive XBT survey. A combination of T5 and T7 XBTs were dropped along this track then down another ascending track. At 0900 (March 7) a test was carried out on the ships rescue boat and further in-situ observations of surface temperature were made. Samples of the local benthic fauna were collected at 0900 on March 8, in very calm conditions, with some cloud cover. Finally we turned back to the northwest along another satellite track towards Noumea with closely spaced XBTs launched along a shallow bottom (~ 600 m). We completed the cruise on reaching Noumea at 0800 on Friday April 9.

Diplomatic Clearances

Permission to conduct scientific research in the waters of New Caledonia, Vanuatu and Fiji were obtained before the cruise. We have undertaken to distribute the results obtained from the cruise, to appropriate organizations within each country, once processing and analysis tasks have been completed.

Summary

This was a very successful cruise. All the major scientific objectives were completed in excellent conditions. In general the ship and its equipment performed well and allowed the collection of all required observations. We note however, that the operation of ASHTEC 3DGPS was certainly effected by 'teething' problems. Given that this was the first cruise after installation this is perhaps not unexpected. Since this equipment was specified as being essential to the aims of the cruise in the initial proposal, it was disappointing that it was not installed earlier to allow for such problems to be corrected well before our cruise. The INMARSAT B unreliability also needs to be corrected in future cruises.

Personnel

Scientific

Ken Ridgway[1, 2]	Chief Scientist	CMR
Rick Bailey[1]	PI	CMR
Richard Coleman[2]	PI	University of Tasmania
Ian Barton[1]	SST project	CMR
Anne-Marie Catchpole[2]	Graduate student	University of Tasmania
Susan Ferguson[2]	Graduate student	University of Tasmania
Mark Wright[1]	CTD support	RAN
Neil White[1]	CTD support	CMR
Ken Suber[2]	SST project	CMR
Jim Mansbridge[2]	CTD support	CMR
Lisa Cowen[1]	XBT comparisons	JAFOOS (CMR/BOM)
Lindsay Pender[1, 2]	Computing	CSIRO ORV
Ian Helmond[1]	SeaSoar	CSIRO ORV
Phil Adams[1, 2]	Electronics	CSIRO ORV
Val Latham[1, 2]	Hydrochemistry	CSIRO ORV
Rebecca Cowley[1, 2]	Hydrochemistry	CSIRO ORV
Mark Rayner[1, 2]	Hydrochemistry	CSIRO ORV

1 Only on first leg
2 Only on second leg

Crew

Richard Dougal	Master
Arthur Staron	Chief Officer
Paul Ware	Second Officer
John Morton	Chief Engineer
Greg Pearce	First Engineer
Dennis Cashman	Second Engineer
Jannick Hansen	Bosun
Paul Bailey	I. R.
Simon Smeaton	I. R.
Terry Ganim	I. R.
Wayne Browning	Greaser
Ron Culliney	Chief Steward
Gary Hall	Chief Cook
Robert Pengkerego	Second Cook

Acknowledgments

I would like to acknowledge the professionalism of the ORV staff. I was impressed with their competence and general ability to get things done in all circumstances. I would also like to thank all members of the scientific staff who worked so very well as a team, obtaining data of the highest quality. The assistance provided by the ship's crew was of a very high standard. There was a general desire to facilitate all aspects of the scientific activities and they displayed a keen interest in all proceedings. This contributed to a very positive atmosphere throughout the cruise and made it a very satisfying experience both on a scientific and a personal level.

K. R. Ridgway, Chief Scientist.